Chapter 11

Afforestation and Forests at the Dryland Edges: Lessons Learned and Future Outlooks

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Summary: In the Drylands of Northern China, such as the Loess Plateau region, a buffer zone of planted forests—a "Green Great Wall"—has been created in the last five decades. These government programs have often generated unintended environmental consequences, and have failed to achieve the desired benefits. Planted forests withhold erosion, dust storms and silting of streams but may reduce stream flow due to higher water use with serious consequences for water management. In spite of contrary expectations, afforestations improve regional climate conditions only insignificantly in the temperate zone. Cost-effective, ecologically useful forest policy in the Drylands requires the consideration of local conditions, and of alternatives such as restoration of grasslands and shrublands. The negative impact of expected rising temperatures on vitality and survival of forests needs to be taken into account as well.

11.1 Introduction

Forests provide many ecosystem services and benefits to society such as regulating water resources and soil protection. In the DEA region, forests are scarce (see Table 4.1 in Chapter 4 of this book). Forest restoration plays an important role in rehabilitating of degraded and over-exploited lands. China has invested great efforts in country-wide afforestation and forest conservation in order to stabilize water supply and reduce soil erosion and desertification.

Recent studies suggest that the effects of afforestation are ambivalent in the drought-threatened drylands. Water consumption of man-made forests may contribute to water scarcity and aridification, and may not achieve the goals of environmental protection (Jackson et al., 2005; Sun et al., 2006; Andréassian, 2004; Brown et al., 2005; Wang, Y. et al., 2008). Projected changes in global climate pose a further challenge on dryland ecosystems, as relatively small changes in the moisture balance may lead to considerable ecological shifts. Forests may even become a factor of increasing climate forcing (Drüszler et al., 2010; Gálos et al., 2011; Mátyás et al., 2009).

At the potentially retreating xeric limits of forests in the meeting zone of steppe and woodland, afforestation and restoration of natural conditions should be carefully considered. Especially concerns about hydrology and climate should be weighed when making decisions about land use changes (Cao, 2008; Cao et al., 2011; Mátyás, 2010b).

In order to put the issue into a wider perspective, the chapter introduces also examples from other countries where ecological conditions are comparable to the DEA drylands, such as from the United States, and from the forest steppes in Russia and Hungary, without the intention to comprehensively survey and assess the global situation of dryland afforestation.

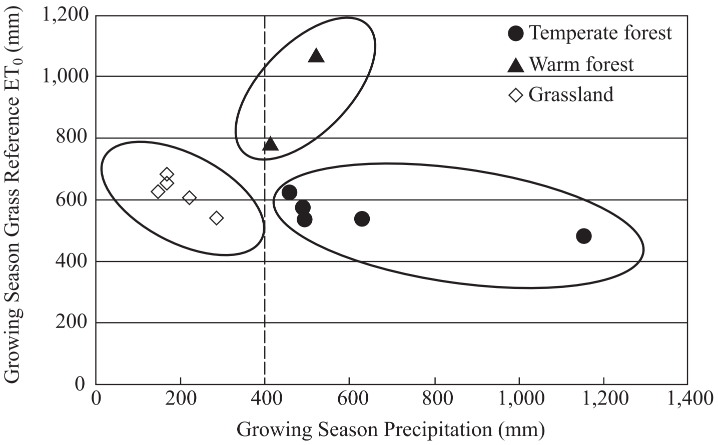

Fig. 11.1 Growing season precipitation and grass reference evapotranspiration (i.e., P-ET) are major drivers for zonal vegetation distribution. Data are derived from an ecohydrological study with sites in the United States, China, and Australia. The figure shows grassland sites (cold steppes and milder-climate shrublands), poplar plantations where precipitation exceeds 400 mm (warm forests), respectively temperate forest sites (Sun et al., 2011a)

11.2 Vegetation Zonation and Climate

Precipitation and temperature are the ultimate drivers of vegetation distribution on earth. Globally, zonal forests are generally found in areas where annual precipitation exceeds evapotranspiration, and thus forests are sources of surface water resources. For example it is estimated that 50% of US water supply comes from forest lands (Brown et al., 2008). Water use by temperate forests is generally less than 700 mm during the growing season, suggesting that ecosystem water use (tree transpiration + evaporation) is limited by energy and water availability (Fig. 11.2) (Sun et al., 2011a). Analyzing temperate grassland and forest sites in the USA, Sun et al. (2011a) found that in the warm-temperate zone forests require at least 400 mm of precipitation in the growing season to sustain desired functions, and grassland and scrub lands are found at sites where growing season precipitation is below 400 mm (Fig. 11.1). Interestingly, atmospheric precipitation was barely sufficient for most ecosystems among the 16 sites in the USA, with only one exception in the humid subtropical region (in Fig. 11.1).

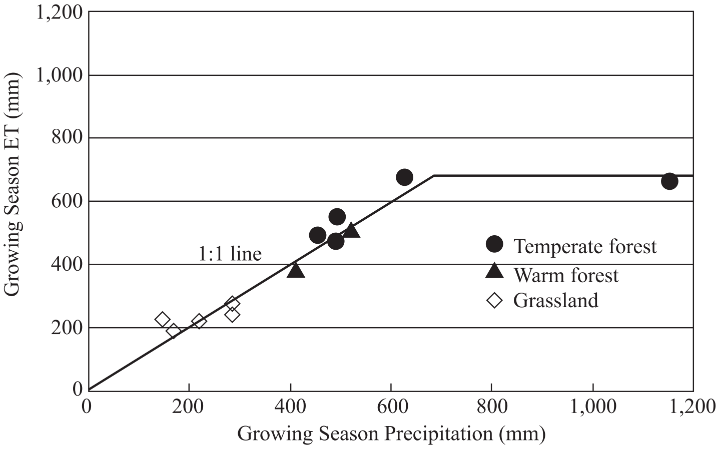

Fig. 11.2 Water use (growing season evapotranspiration vs. precipitation) of grasslands and forests across ecohydrologic study sites

11.3 Climate Forcing Effect of Forests: Ambiguous Conditions at the Dryland Edges

Climate model simulations prove that land cover, i.e., vegetation, has an important role in climate regulation. Due to their higher leaf area, forests display a high photosynthetic activity and transpiration. leaf area index (LAI) of deciduous forests exceed that of croplands by a factor of approximately 1.4–1.7 (Breuer et al., 2003). Forest cover modifies the hydrological cycle, albedo and turbulent fluxes above land surface. Thus, forests have both a direct and indirect effect on factors contributing to both natural and also to anthropogenic climate forcing (land use change, forest destruction or afforestation). Half a century of land use changes may be enough to cause significant regional changes of climate (Drüszler et al., 2010).

Although it is generally believed that planting forests may mitigate climate change impacts and slow down the aridification process, current views on the role of temperate forests are contradictory and fragmentary. Some scientists even state that—contrary to the tropics—afforestation in the temperate zone may have climatically "little to no benefits" (Bala et al., 2007; Bonan, 2008). Forests have a lower albedo than crops (e.g., coniferous forests: 0.14 vs. crops: 0.24; Breuer et al., 2003), which is compounded by the fact that evergreen (coniferous) forest canopy masks highly reflective winter snow cover. The lower albedo of forest cover may cause somewhat higher summer and winter temperatures, thus worsening drought. Contradicting investigations at the Canadian prairie-woodland border (Hogg and Price, 2000) indicate, however, that forest cover may have a positive effect. Summer temperatures were significantly lower where deciduous woodland cover remained. The deciduous forest mainly causes anomalies in summer; temperatures were cooler, mean precipitation was higher and length of growing season increased. It seems that the balance between albedo and actual evapotranspiration determines whether there is a cooling or warming effect. The surface roughness of the forest crown layer leads to different aerodynamic conductance, which alters cloudiness and creates additional atmospheric feedback (Drüszler et al., 2010).

Applying the climate model REMO [1] , Gálos et al. (2011) have studied the regional feedback effect of afforestation for projected climatic scenarios in the transition zone between forest and grassland climate in Hungary. The climate of the recent past (1961–1990) was compared to projections for the period 2070–2100, when precipitation is expected to decline by 24% (Gálos et al., 2007). The effect of transpiration of the additionally planted forests (d_{Tr}) on precipitation increase (d_{P}) was investigated for a realistic, 7% increase of 20% of the present forest cover, and also for an extreme scenario, where all available agricultural land would have been afforested, resulting in 92% of forest cover (Fig. 11.3).

The mitigating effect of higher evapotranspiration on decreasing precipitation appeared relatively modest. Even the unrealistic maximum afforestation could lower the projected precipitation decrease by one quarter only (<6% in Fig. 11.3). It may be suspected that part of the precipitation feedback is carried into neighboring regions by westerly winds.

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[1] REMO is a climate model developed at the Max Planck Institute for Meteorology, Hamburg, Germany

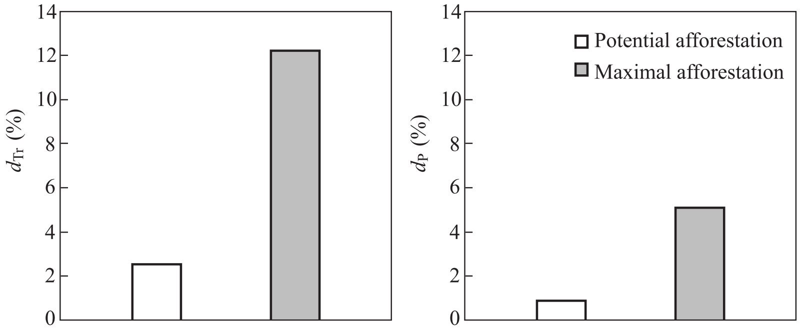

Fig. 11.3 Feedback of planned afforestation on future climate conditions in Hungary. (a) projected transpiration increase (d_{Tr}); (b) projected precipitation increase (d_{P}), for a realistic (light columns) and an extreme scenario (dark columns). Explanation is in the text (Gálos et al., 2011)

The impact of energy balance on climate due to past land use changes has also been investigated in Hungary. Lower albedo, as well as changed sensible/latent heat ratios resulted in a rise of summer temperature in the last century in afforested regions. The increase remained however relatively modest, compared to the overall anthropogenic rise of temperature (Drüszler et al., 2010).

When planning and assessing afforestation in semi-arid conditions, the projected climate of the far future has to be carefully considered because of the extreme long-term character of forest management. Stability and growth of forests depend on available water resources and temperature conditions of the future. Across the temperate zone, a relatively rapid increase of annual mean temperature has been observed in recent decades, and the dryland zone in China and Mongolia is no exception. In the last half century, both average temperatures and climatic extremes increased (Qi et al., 2012). For instance, average temperatures in Mongolia increased by more than 2 °C since 1940 and nine out of the ten warmest years occurred after 1990 (Lu et al., 2009). In North China, frequency of droughts intensified during the past several decades, leading to an unprecedented increase of dry areas (Piao et al., 2010). Growing season anomalies have been generally increasing in China in the 2000s: drought events got significantly stronger in North China and soil moisture declined (Zhao and Running, 2010).

At the same time, analyses of impacts on forests in dry regions are limited or sporadic. For instance, the Food and Agriculture Organization of the United Nations (FAO) global statistics do not yet calculate with the effect of forest cover loss due to aridification (FAO, 2010). There are reports from western North America (Allen et al., 2010; Hogg and Price, 2000), while impacts in Eastern Europe, Central Asia and the Chinese drylands are less known (Zhang et al., 2008b; Piao et al., 2010; Mátyás, 2010a). Experiments on growth and yield confirm the negative impact of rising temperatures on vitality and survival (Mátyás et al., 2010; Fig. 11.4).

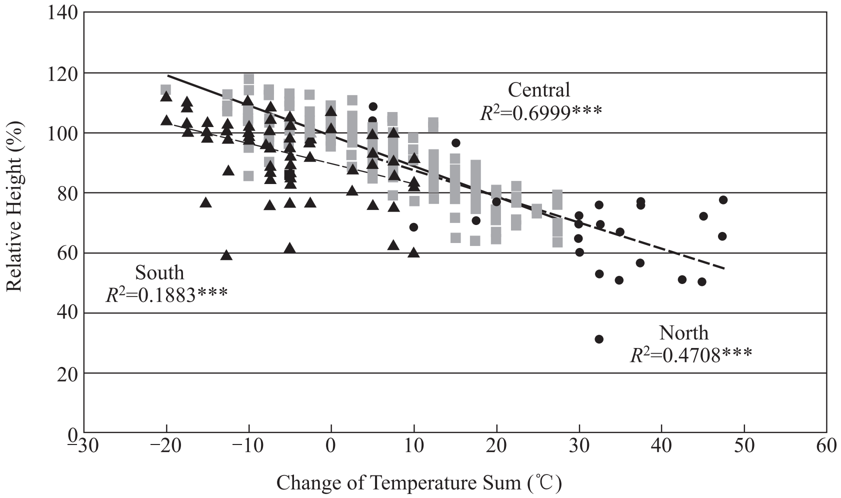

Fig. 11.4 Growth response of geographically transferred Scots pine (*Pinus sylvestris*) populations (provenances) to simulated warming. The increase of annual temperature sum (in °C degree-days) resulted decline of relative height irrespective of origin (central, northern or southern populations). Re-analyzed data of six Russian experiments (Mátyás et al., 2010)

11.3.1 Low Elevation Xeric Limits: Vulnerable Forest—Grassland Transition

Xeric (or rear, trailing [1]) limits are at the low latitude, low altitude end of distribution ranges of temperate forests, where presence/absence of species is determined by climatic aridity (Mátyás et al., 2009). Xeric limits appear in semi-arid zones along the foothills of mountain ranges, and at the edges of dry basins such as in Central Asia or in the DEA region (for maps, see Chapter 4 in this book). Xeric limits follow the southern edge of closed forests westwards through Russia and the Ukraine as far as Hungary. Temperate xeric limits exist also on other continents, along the edge of the Prairies of North America, notably from the southwest states of the USA northward into Alberta (Canada). At the xeric limit, the closed forest belt forms a transition zone or ecotone toward the open woodland or forest steppe, which dissolves with decreasing precipitation

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[1] The terms in brackets refer to events of postglacial migration, where xeric limits represent the "rear" end of shifting vegetation zones, triggered by gradual warming

into the true steppe or grassland. The forest/grassland ecotone is dependent on a volatile minimum of rainfall and is therefore sensitive to prolonged droughts. The physical characteristics of the land surface (e.g., albedo, evapotranspiration, roughness etc.) as well as carbon cycle and ecological services are strongly affected by land use policy and changes in this transition zone.

The forest-grassland transition zone is especially vulnerable to expected climatic changes in flat lands because of the magnitude of the *latitudinal lapse rate*. It is generally known that the altitudinal lapse rate for temperature (i.e., the rate of change with increasing elevation) is 5.0–6.5°C/1,000 m. The latitudinal (south to north) lapse rate is less recognized. In the temperate zone its mean value is around 6.9°C/1,000 km—a difference of three magnitudes. This means that predicted changes of temperature affect disproportionately larger tracts of plains as compared to mountainous regions. A temperature increase of only +1°C causes a shift upwards along a mountain slope of approximately 170 m. On a plain, the same change triggers a shift of close to 150 km (Jump et al., 2009). This explains the much greater vulnerability of rain-dependent vegetation on plains.

11.3.2 Management of Forests—Plantations vs. Close to Nature Ecosystems

In most temperate zone countries, returning to close-to-nature forest management seems to be the general trend to mitigate impacts of environmental change. The concept is based on the hypothesis that stability and persistence of forest ecosystems are warranted by plant communities evolved during the past millennia, and enhancing the naturalness of forests will also enhance their stability. The hypothesis is challenged at the xeric limits by numerous constraints, such as

- Long-lasting human interference and land use have caused a partial or total loss of natural (woody) plant cover,
- Number of native species expected to tolerate potential environmental changes is usually low,
- Functioning of close-to-natural systems is disturbed by indirect human effects (e.g., grazing, air pollution) and by the expected climatic changes and extreme events.

These constraints necessitate a revision of the commitment to naturalness, first of all in regions of high drought risk. Across the DEA region, plantation forest has been generally introduced. Recent changes in forest policy support a return to close-to-nature conditions in China (Xu, 2011). It is believed, however, that the carefully planned and active human interference is unavoidable in dry lands because a long-term adaptation to environmental changes has to be considered, especially at the xeric limits.

11.4 Effects of Forest Management on Forest Hydrological Balances in Dry Regions: A Comparison of China and the United States

Compared to grasslands or short-cycle crops, forests have large above-ground biomass and deeper roots. Therefore forests can use more water (Wang, Y. et al., 2011) and can capture larger amounts of carbon through photosynthesis as carbon and water cycles are highly coupled (Law et al., 2002; Sun et al., 2011b). World-wide vegetation manipulation experiments show that forest removals reduce water use, i.e., evapotranspiration (ET), and thus increase watershed stream flow. On the other hand, reforestation or afforestation on watersheds previously covered by native grassland can reduce stream flow due to an increase in ET (Andréassian, 2004). Forests have higher ET than harvested sites or croplands, so groundwater table levels are generally lower under forests (Sun et al., 2000). Figure 11.5 demonstrates one such case in the forest steppe

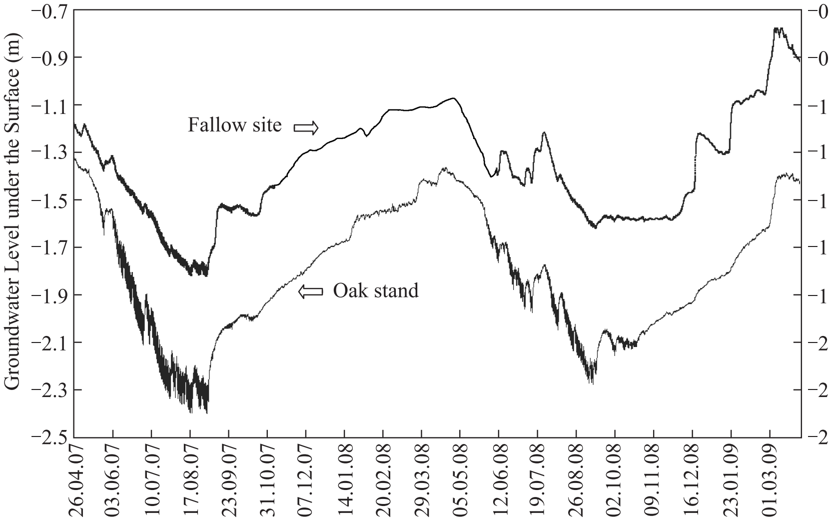

Fig. 11.5 Water table fluctuation in the course of one year under an oak forest (*Quercus robur*) and a neighboring grassland (fallow) site in the forest steppe zone of Hungary (source: Móricz et al., 2012)

region of Hungary where the forest stand's ET was 30% higher than that of neighboring grassland.

Earlier long-term forest hydrologic studies focused on deforestation effects, floods and sedimentation (Alila et al., 2009). Hydrologic studies on the consequences of forestation have emerged in the past decade (Scott et al., 2005; Sun et al., 2006; Wang, Y. et al., 2011). In particular, evaluation of worldwide reforestation campaigns has shown that human intervention requires a closer look at the unexpected consequences. An emerging question is how reforestation in different climatic regimes affects watershed functions such as water yield (Sun et al., 2006). The potential water yield reduction following afforestation for bioenergy development, ecological restoration, respectively for climate change mitigation, has drawn renewed attention to the relations between forests and water resources in watersheds (Calder, 2002; Brown et al., 2005; Jackson et al., 2005; Trabucco et al., 2008; Malmer et al., 2009) and on a regional scale (Ellison et al., 2011). The hot debate on "planting" or "not planting" policies is especially relevant in arid regions or regions with scarce water resources (Greeff, 2010).

11.4.1 China

The comprehensive forest hydrological studies that address forest-water relations did not start until the 1990s. Important findings emerged rapidly in the past two decades (Wei et al., 2008). In dry northern China, such as the Loess Plateau region, empirical and modeling studies confirm that that forest vegetation and associated soil conservation engineering had a significant influence on watershed stream flow (Zhang et al., 2008a, 2008b; Wang, Y. et al., 2011; Wang, S. et al., 2011).

Recent forest hydrology studies have detected that land cover and land use changes played a substantial role in stream flow reduction downstream (Zhang et al., 2008a, 2008b). A water balance modeling study suggests that if 5.8% and 10.1% of the study area on the Loess Plateau is planted with trees, stream flow will decrease by 5.5% and 9.2%, respectively. The rate of stream flow reduction decreased from dry to wet area in the Loess Plateau region (Zhang et al., 2008a). In another 40-year retrospective study (1959–1999), Zhang et al. (2008b) examined stream flow and climate data from 11 catchments in the Loess Plateau to investigate the response of stream flow to land use/cover changes. They found that all catchments had significant reductions in annual stream flow of -0.13 mm to -1.58 mm per year between 1971 and 1985. Land use/cover changes accounted for over 50% of the reduction in mean annual stream flow in 8 out of the 11 catchments, while in the remaining three watersheds precipitation and potential evaporation were more important. Among the soil conservation measures, construction of sediment-trapping dams and reservoirs, and the diversion for irrigation appeared to be the main cause of reduced stream flow.

To understand the effects of vegetation on stream flow in the Loess Plateau region, Wang, Y. et al. (2011) constructed multi-annual water balances for 57 basins to estimate annual evapotranspiration (ET) and runoff for forest lands and non-forest lands. Mean annual precipitation was 463 mm and the corresponding averages of annual ET and runoff were 447 mm and 16 mm for forest lands, and 424 mm and 39 mm for non-forest lands. Although the difference in annual runoff was only 23 mm, this is a large difference in relative terms, being equivalent to nearly 60% of annual runoff from non-forest lands. The authors argue that large-scale afforestation may have serious consequences for water management and sustainable development in dry regions because of runoff reduction.

11.4.2 United States

Since the late 1930s, numerous "paired watershed" studies have been conducted in the United States to examine forest management effects (harvesting with various intensities, species conversion, farming as an alternative), on water quality and yield across various climatic and topographic conditions (Ice and Stednick, 2004). In general, humid areas with high precipitation have higher hydrologic response in absolute terms, but dry areas with low water flow can have a higher relative response. For example, clear-cutting a deciduous forest in the humid south-eastern USA, with an annual precipitation >1,800 mm, can result in an increase in stream flow of 130–410 mm per year, which is 15%–40% of undisturbed control watersheds, while the same management practice in the drier area of northern Arizona with an annual precipitation of 500–600 mm may result in a water yield increase of 60 mm or >40% of undisturbed control watersheds. Zou et al. (2009) summarized century-long vegetation manipulation experiment studies in the Colorado River Basin that provide a bounty of knowledge about effects of change in forest vegetation on stream flow in water-deficit areas. The watershed is situated at the headwaters of streams and rivers that supply much of the water to downstream users in the western United States. The authors found that vegetation can be managed to enhance annual water yields while still providing other ecological services. The effects of vegetation manipulation on stream flow are associated with the precipitation/elevation gradient and, therefore with vegetation type. An annual water yield increase between 25 mm and 100 mm could be achieved by implementing vegetation manipulation in the high elevation subalpine and mixed conifer forests, the lower ponderosa pine forests and portions of the low elevation chaparral scrublands. The annual precipitation was generally above 500 mm in areas where a 100 mm increase in stream flow was achieved. Negligible or small increases in water yield were observed from treating sagebrush, pinyon-juniper woodlands and desert scrubs, with an annual precipitation below 500 mm. This study suggests that reforestation is likely to cause relatively larger hydrologic effect in areas where precipitation is roughly balanced by evapotranspiration demand, i.e., above 500 mm.

11.5 Past and Future of Forest Policy in Dryland Regions of China

11.5.1 Causes and Consequences of Expanding Desertification

In China, deserts and semi-desert lands cover an estimated 150 million ha., while another 140 million ha. of pastures and croplands are threatened by desertification, mainly because of human activities such as deforestation and overgrazing (Fullen and Mitchell, 1994). One third of the desertification is attributed to overharvesting of forests (Liu et al., 2008); although droughts and climate change contribute as well. As a consequence, the Gobi desert is expanding by an estimated rate of 246 thousand ha. per year (Ratliff, 2003). In the most seriously threatened Loess Plateau region of China, 43 million ha. are affected by desertification. In addition, 99 million ha. of land is subject to salinization and alkalization (MOF, 1995; see also Chapter 13 and Chapter 4 in this book). Soil erosion causes heavy sediment loads and deposition in river beds especially on the Loess Plateau. There is general agreement that increasing flood damages are partly caused by soil erosion that clog drainage channels and reduce the holding capacity of many reservoirs.

11.5.2 Shelterbelt Development and Sand Control Programs in China

Soil conservation practices were initiated in the 1950s and were aimed at reducing upland soil erosion and sedimentation of rivers (e.g., on the Yellow River). Therefore, vegetation restoration, especially afforestation, has been encouraged as an effective measure for controlling soil erosion, to alleviate flash floods, increase forest productivity and diversify rural incomes. Furthermore, afforestation is increasingly viewed as an effective measure of carbon sequestration to partially offset CO_2 emissions. This policy has brought about an extensive conversion of grassland, shrubland and slope farmland into forest plantations (Wang, Y. et al., 2011).

To combat environmental deterioration, a buffer zone called as "Green Great Wall" has been envisaged along the transition from the humid farming region to the arid and semi-arid grazing zone to block expanding desertification. Since the green belt stretches across Northeast, North and Northwest China, it has been named "Three-North Shelterbelt Development Program". The program was launched in 1978 and aimed to green a total of 23.74 million ha. by 2010 (CFA, 2007; see also Chapter 13 in this book).

The program has progressed in several phases. During the first phase (1979–1985), more than 11.2 million ha. were planted, out of which over 6 million ha. were successful. In the second phase (1986–1995), about 10.6 million ha. of land were planted, resulting in 6.8 million ha. of fully stocked forest. On the whole, between 1978 and 1995, 10% of the desert land was restored, 13 million ha. of agricultural land were protected by the planted forest, and 10 million ha. of pasture land were converted to forest. During this period about 10 million US dollars from the central government budget and about 40 million USD were locally provided annually to finance this program.

In the third phase (1995–2000), the work continued with priority in the regions of Liaoning, Jilin, Heilongjiang, Beijing, Hebei, the Kerqin Desert, the Mu Us Desert, the Loess Plateau north of Wei River, the southern part of Luliang Mountains and the Hexi Corridor, etc. (Zhang et al., 1999). Apparently, some corrections have been made after problems with planted trees had been reported. The use of native species and of more shrubs in the restoration programs has been encouraged by both academic scholars and governmental officials. For example, in the plan made in 2000, 40% of an estimated 9.5 million ha. potential afforestation area was foreseen to be planted with shrubs (SFA, 2000). To supplement the Three North Shelterbelt Development Program in order to establish a second belt to block sand/dust storms was launched in 2000. The program is often called as the Sandstorm Control Program for Areas in the Vicinity of Beijing and Tianjin). The objective to control 6.12 million ha. of land at risk of desertification was achieved and 101,200 persons have been reallocated (CFA, 2007).

11.5.3 Debates and Critics About the achievements of the Past Programs

The initiative of greening the three regions of the North started in the 1960s, and resumed and intensified after the country suffered from a big flood in 1998 and from frequent sand storms in North China, including Beijing. While the achievements had been widely acclaimed the projects increasingly stirred criticism and were debated. It was pointed out that afforestation often generated unintended environmental, ecological, and socioeconomic consequences, and has failed to achieve the desired ecological benefits (Cao, 2008; Cao et al., 2011; Xu, 2011; see also Chapter 13, in this book).

It has been argued that the arid and semi-arid regions are mostly not suitable for tree growth which requires a lot of water and makes the land even drier, leading to more severe soil erosion and desertification. The majority of the vegetation restoration programs — including the Three North Shelter-Forest and the Regional Sandstorm Control programs — involve planting trees in areas where annual precipitation is less than 400 mm. As a result, water yields have dropped by 30%–50% and vegetation cover has decreased by 6.1% on the semi-arid Loess Plateau (Sun et al., 2006). In the whole DEA region, although forest cover increased by 22 tsd. km^2 between 2001 and 2007 but the total area of woody savannas and shrublands decreased nearly five-fold (91 tsd. km^2) according to IGPB's classification (Chapter 4 in this volume)

In the government plans, trees were over-planted while subsequent care was disregarded, and unsuitable species were used. For example, aspen (*Populus tremula*) which is excessively water-demanding, accounts for almost half of China's reforestation (Liu et al., 2008). Exotic tree species were being planted in arid and semi-arid conditions, where perennial grasses with their extensive root systems would better protect the topsoil (Xu, 2011). Other experts (e.g., Yang and Ci, 2008) argue that afforestation is not equivalent to forestry or tree planting, and is closer to the term of "greening" as a large part of restoration was executed with shrubs (CFA, 2007). This could be true at the later stage when the problem was discovered.

Economy is another aspect of the debate. Critics contend that the massive tree planting efforts are expensive — the Green Great Wall being an expensive band aid on a century-old wound. At the turn of the century the central government made a strategic realignment of the former afforestation projects in the whole country, and integrated them into the State Key Forestry Programs (SKFPs), including the Natural Forest Protection Program (NFPP), the Cropland Conversion to Forests Program (CCFP), the Key Shelterbelt Development Programs for the Three North and the Yangtze River Basin (3Ns and YRB), and the Sand Control Program for the Beijing and Tianjin area (SCP). For the SKFPs, China has invested a total of 183.5 billion RMB (ca. US $22 billion) from 1998 to 2006 (Wang, G. et al., 2008). A majority of the programs are concentrated in the arid and semi-arid zones of the North and Northwest.

Such huge investments raise the question of economic efficiency. Many studies have been conducted to assess the results. Efficiency is however not the only goal. The afforestation projects also aim to alleviate poverty improvement of food supply and population reallocation. Local studies (e.g., Zhi et al., 2004;

Kong, 2004) are difficult to generalize the assessment of the whole program. To assess the ecological, economic and social impacts of the programs in their complexity remains a challenging task.

11.5.4 Lessons Learned from Past

As a result of mixed experiences with the past programs and due to increasing criticism, China's forest and environmental policy has been changing in the recent times. It was recommended to shift from political solutions to economic solutions, e.g., paying farmers to reduce livestock, raising water prices to encourage conservation, and temporarily relocating local inhabitants away from arid areas to allow recovery (Williams, 2002). The emphasis has been shifted from tree plantations to natural ecosystem restoration, and an engineering approach has been replaced with a more comprehensive socio-economic and ecological attitude which is usually more cost-effective. Shrub and grassland restoration has been qualified as equally important as the forest restoration according to the "Green for Grain" policy initiated in the early 2000s. A more social approach has been increasingly adopted like providing economic incentives for farmers to reduce livestock and relocation to other areas or cities (Ratliff, 2003).

The updated policy recommendations may be summarized as follows. The objective is greening or vegetation restoration instead of just afforestation. Greening should be tailored to local environmental conditions and the right plant species or species composition should be used, and considering alternatives such as shrubland and grassland restoration. The emphasis should be placed on the results achieved rather than on efforts invested. Long-term monitoring must be implemented to provide the data needed to develop a cost-effective, scientifically based restoration policy (Cao et al., 2011).

11.6 Conclusions

Current views and experiences about the role of forests at dryland edges are contradictory. Although forests may provide multiple ecological benefits, reforestation or the afforestation on watersheds previously covered by native grassland can reduce stream flow due to higher water use. Therefore large-scale afforestation may have serious consequences for water management and sustainable development because of runoff reduction. In the drylands of northern China, such as the Loess Plateau region, studies confirm results achieved in other parts of the world that forest management and associated soil conservation engineering have a significant influence on watershed stream flow.

Forests directly influence atmospheric climate forcing. Therefore it is believed that forests mitigate climate change impacts such as warming and aridification. According to some investigations, the forest cover at dryland edges has a positive effect on lowering summer temperatures. Detailed studies indicate that in spite of increased evapotranspiration, precipitation changes only insignificantly in afforested regions. At the same time, the lower albedo of forests may cause a moderate temperature rise.

In China, deserts have been expanding, mainly because of deforestation and overgrazing. Huge efforts have been invested in the arid and semi-arid regions to combat desertification and soil erosion and to control the environmental deterioration. A buffer zone of planted forests—a "Green Great Wall"—has been created in the last five decades in the areas where annual precipitation is often less than 400 mm. The politically directed afforestation programs had often generated unintended environmental, ecological and socioeconomic consequences, and had failed to achieve the desired benefits. Due to mechanistic implementation of projects, planting of forests has often led to more severe soil erosion and desertification. To consider the relation of expenditures to benefits achieved is essential, but afforestation projects are intended not only to improve ecological conditions but also to play an important socioeconomic role.

A cost-effective, scientifically based forest policy in the drylands requires the consideration of local environmental conditions, of alternatives such as restoration of grasslands and scrublands, and the use of the proper technology. Experiences from the United States confirm that vegetation can be successfully managed to enhance annual water yields while still providing other ecological benefits. Carefully planned human interference is therefore essential in dry lands, to achieve a policy of restoration and of adaptation to the long-term effects of expected environmental changes.

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